In a muon's lifetime: From Fermi's constant to "calibrating" the sun

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The muon group at Illinois is performing three experiments at the Paul Scherrer Institute all measuring the muon lifetime with high precision. The MuLan experiment uses a simple soccer-ball like scintillator array to detect the decay positrons. We collected twice 10^{12} muon decays in two different target materials to obtain the final precision of 1 ppm which will give a 20 times better determination of the Fermi constant G_F. A first result was recently published [1] which already improved the precision of G_F to 5 ppm. The muon capture experiment MuCap uses a negative muon beam stopped in a time projection chamber as an active target filled with ultra-pure hydrogen gas. The elementary capture process $\mu^-+p \rightarrow n+\nu$ offers a rare (0.15%) but additional disappearance channel. The measured difference of the positive and negative muon's lifetime determines the rate of the capture process to a final precision of 1%. This can be used to derive an improved value of the proton's pseudoscalar form factor g_P to 7% precision. A first result $g_P = 7.3 \pm 1.1$ has been published [2]. This is a first precise, unambigous determintation of g_P and an important test of QCD symmetries. Recently, we started a new experiment, MuSun [3], that will start a first commissioning run at the end of 2008. Here, a measurement of the $\mu^-+d \rightarrow n+n+\nu$ provides a benchmark of the understanding of weak processes in the two nucleon-system. It was shown, that other weak reactions involving the two nucleon system ($pp \rightarrow de^+\nu$ or $\nu+d$ reactions) are related to the same low-energy constant, characterizing the two nucleon system at short distances. This constant is not well constrained and therefore the MuSun experiment comes closest to calibrating these basic astrophysical reactions under terrestrial conditions.

[1] Phys. Rev. Lett. 99, 032001 (2007)
[2] Phys. Rev. Lett. 99, 032002 (2007)
[3] http://www.npl.uiuc.edu/exp/musun/documents/prop07.pdf